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Listening to the response of bat and bush-cricket communities to management regimes of powerline clearings

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Abstract

Linear transportation infrastructures (LTIs) are established drivers of habitat fragmentation and barrier effects. Yet, they represent an increasing surface of managed seminatural habitats where increased consideration of biodiversity outputs is needed in an era of global biodiversity decline. A combined effort by both scientists and stakeholders is, therefore, needed to evaluate the promises and limits of these alternatives so that they best achieve their conservation potential. Our study explores the effects of forest powerline clearings on biodiversity, as well as the potential benefits of integrated vegetation management (IVM) as alternatives to clear-cuts. We recorded the acoustic activity at 35 pairs of forest/clearing stations in two forested regions of France in 2021. Our results suggest that powerline clearings represent increased movement opportunities for bats and, most particularly, edge-foraging species. They also provide suitable habitats for bush-cricket species, particularly species requiring thermophilic conditions. We detected no direct benefit from IVM on bat communities. However, bush-cricket communities appeared richer, more acoustically active, and statistically different from adjacent forests in clearings favoring secondary vegetation compared with clear-cut ones. This collaborative study provides data on understudied taxa in the context of LTIs and sheds light on conservation promises and limits associated with their management.

KEYWORDS

acoustic, community, edge-effect, management, powerline

1 | INTRODUCTION

Linear transportation infrastructures (LTIs), that is, railways, pipelines, or roads, represented a network of 1.3 million kilometers in France in 2020 (Ministère de la

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Transition Ecologique, 2022), 8% being aerial powerlines (https://analysesetdonnees.rte-france.com/reseaux/evolution-reseau). However, in the context of climate change and new public decarbonization policies, the number of high voltage powerlines is thought to increase (RTE, 2021). LTIs are known drivers of direct habitat destruction, barrier effects, and habitat fragmentation (Ibisch et al., 2016). The latter acts as a major stressor on natural ecosystems as the splitting of natural habitats into smaller and isolated areas and associated habitat loss and barrier effects result in long-term negative effects on biodiversity (Krauss et al., 2010). Additional pervasive effects from the development of LTIs include light, noise, chemical pollution, and direct mortality (Biasotto & Kindel, 2018; Litvaitis & Tash, 2008; Richardson et al., 2017). These perturbations indeed integrate the landscape of fear perceived by the fauna, modifying their use of space (Bleicher, 2017). For instance, a "road-zone" effect has been described on mammals, birds, or amphibians that can range from a few meters to kilometers around infrastructures (Benítez-López et al., 2010).

Although LTIs have strong negative impacts on biodiversity, they still represent shelters for tolerant taxa and might even represent biodiversity refuges (Le Viol et al., 2009) and dispersal corridors through human-dominated landscapes (Vergnes et al., 2013). In the face of biodiversity erosion and growing pressure from global changes, conservation efforts focused on natural protected areas are likely insufficient (Pressey et al., 2007). There is, therefore, a need for increased conservation efforts in human-modified landscapes (Le Viol et al., 2009; Ranius et al., 2023). Promoting biodiversity in human-dominated landscapes (Kueffer & Kaiser-Bunbury, 2014; Persha et al., 2010), including LTIs (Edwards & Abivardi, 1998; Rosenzweig, 2003), is therefore crucial. Some opportunities for biodiversity enhancement on lands altered by LTIs already arose in line with both biodiversity conservation and ecosystem functioning objectives (Hobbs et al., 2009). As land management practices evolve under and around LTIs as a response to biodiversity policies, scientific assessments are needed to evaluate their limits and potential benefits (Ouédraogo et al., 2020; Villemey et al., 2018).

LTIs are original ecological features that can be seen as hybrids between habitat gaps and edges. They are made of a great edge-to-area ratio compared with any other habitat clearings but are often included in one habitat type, while edges *strictu senso* designate a separation between two habitats. LTIs are also anthropogenically managed habitats by definition and are maintained in artificial states for operation and maintenance (Lundholm & Richardson, 2010). From an ecological perspective, habitat edges are known to affect biodiversity assemblages by shaping ecological flows, resource accessibility, or species interactions (Ries et al., 2004; Ries et al., 2017). Particular edge features include high stem densities, great species richness, and an increased occurrence of generalist and exotic species (Fahrig, 2003; Harper et al., 2005). Edges are, therefore, places of greater stochasticity in recruitment and mortality patterns, which are ultimately driven by the surrounding landscape (Laurance et al., 2007). These ecological features apply to LTIs in various ways depending on the habitat matrix in which they are installed and the type of transportation infrastructure itself.

Powerline clearings constitute a particular case of LTI as the infrastructure is mostly aerial, allowing different levels of vegetation to be maintained beneath the structure itself, from the sparsest to secondary successions. Indeed, specific safety and operating constraints prohibit any close proximity between vegetation and power cables. As a result, approximately. 48,000 ha of vegetation beneath powerlines are managed in France. Clear-cuts are generally maintained since gyro, or manual cutting must be done at special frequencies (3, 6, 9, and 12 years) dependent on the powerline height and vegetation characteristics (i.e., growth speed) in forested areas. However, since 2010, integrated vegetation management (IVM) has begun to develop in European countries as an approach that focuses on the ecological health of areas normally gyro-grinded while still removing vegetation (Renewables Grid Initiative, 2023). IVM aims to lower human pressures on powerline clearings by developing contextually appropriate actions. Methods are, therefore, dependent on local factors and inherently heterogeneous: establishment of tiered edges (by restoration or planting), grazing, mowing, restoration of open habitats (moors, peat bogs), and biomass-related productions (arboriculture, apiculture, and plantations) are all considered. In order to stimulate the development of IVM in powerline clearings, an effort should be dedicated to evaluating their relevance in a conservation context, that is, their biodiversity outputs.

Abundant literature already describes the risks associated with the habitat edges associated with powerline clearings in terms of collision, dispersal barriers, and electromagnetic field effects (Biasotto & Kindel, 2018; Forman, 2014). Yet, potential benefits from powerline clearings habitats have also been documented at the landscape scale on plant diversity (Dániel-Ferreira et al., 2020) and on the dispersal and foraging of several taxonomic groups such as bees (Russell et al., 2005), butterflies (Berg et al., 2011), terrestrial gastropods (Nekola, 2012), birds, and mammals (Askins et al., 2012; Clarke & White, 2008). Only a few studies explored the effects of vegetation management under powerline clearings. Yet, the composition of plant communities in forest powerline clearings has been shown to be directly influenced by the rate and modality of human interventions (Eldegard et al., 2015).

Some studies explored the relationship between powerline clearings and insect communities, with contrasted results depending on the study taxa (Ditsworth et al., 1982; Lampinen et al., 2018; Russell et al., 2005). In the proximity of natural grasslands, appropriate management under powerlines could favor the development of rich, diverse, and abundant grassland communities (Russell et al., 2005). Such management involves leaving logging debris on the ground and spacing out clearing operations (Lampinen et al., 2018). Regarding vertebrates, a recent literature review reported only four reliable assessments of powerline effects on birds and small mammals' richness (Ouédraogo et al., 2020). In these, negative effects were recorded only on the abundance of one forest bird species and a small forest marsupial. These works highlighted (i) an overall lack of quantitative assessments of the powerline corridors' effect on biota, (ii) a need for broad assessments beyond habitat-specific contexts, and (iii) promises from management practices that should be confirmed at various trophic levels.

To provide a broad-scale assessment of the biodiversity footprint of powerline clearings and their management of forest biotas, we worked on two regions of France with a wide diversity of forest habitats and management practices. For this broad-scale assessment to be comprehensive, we worked on two acoustically active yet ecologically contrasted taxa and complementary indicators (Bazelet & Samways, 2011; Jones et al., 2009). Bush crickets (Orthoptera: Tettigoniidae) represent terrestrial invertebrate organisms (Orthoptera) of low trophic levels, rapid life cycles, and small home ranges, and rely on open habitats and secondary vegetation successions. We expected this group to respond to the vegetation structure positively and thereby to management practices favoring meadow/grassland habitats (Gardiner, 2018). In comparison, bats are aerial vertebrate organisms (Chiroptera) of higher trophic levels, longer life cycles, and larger home ranges. They are dependent on the quality of both open (mid- and long-range echolocators) and closed habitats (short-range echolocators) for foraging and roosting, respectively (Denzinger & Schnitzler, 2013). We expect this group to respond to changes at the broader habitat scale.

The present study explores the effect of forest clearings and vegetation management practices beneath high-voltage powerlines on bush-cricket and bat communities. We first expected that open habitats created by clearings may be suitable for bush crickets and used as corridors by bats. Therefore, we hypothesized that the diversity and abundance of these taxa may be higher in powerline clearings than in adjacent forests. However, the niche evolution theory predicts that perturbation and habitat degradation should negatively affect specialist taxa. We thus expected that such an increase in diversity may be associated with a decline in communities' specialization to forest habitats (Blackburn et al., 2004; Kerbiriou et al., 2009). We tested this second hypothesis by computing two community-wide habitat specialization indexes. Finally, we expected that IVM would favor the development of bat and bush-cricket communities independent from forest ones. We tested this assumption by looking at the dissimilarity of forest/clearing community pairs across different vegetation management regimes.

2 | METHODS

2.1 | Acoustic sampling

Because bush crickets produce mating calls and bats produce echolocation for commuting and foraging, it is possible to collect large standardized data sets using recording devices (Jeliazkov et al., 2016; Mariton et al., 2023). Acoustic recordings can provide relative measures of abundance (Mimet et al., 2020) at large spatiotemporal scales (Penone, Kerbiriou, et al., 2013; Penone, Le Viol, et al., 2013). To produce a generalizable assessment, we searched for study sites that (i) were mostly forested, (ii) had powerline clearings, and (iii) hosted both clear-cuts and IVM. Two areas of France satisfied these criteria, namely the planted pine forests of the Landes-Gironde—hereafter simplified as "Landes"—which was sampled in summer 2021 (June 15 to July 10) and the deciduous forests of the "Ardennes" sampled in fall 2021 (September 28 to October 13; Figure 1). The design consisted of pair samplings at powerline clearing edges and 200 m deep in the adjacent forest. Forest specialist vertebrates were indeed shown to peak in abundance 200 m away from forest edges and further deep (Pfeifer et al., 2017).

Stationary recording devices were set that recorded all sounds between 8 and 192 kHz throughout one entire night, from 30 min before sunset to 30 min after sunrise. Two types of recorders, SM2BAT+ (Wildlife Acousitics, Inc.) in "Landes" and Audiomoth (Open Acoustic Devices) in "Ardennes," were used. To limit heterogeneity between the devices, recorders were configured with settings recommended by the French citizen science bat monitoring program Vigie-Chiro (https://www.vigienature.fr/fr/chauves-souris). SM2BAT+ and Audiomoth were tested in parallel in the field to compare their capacity to detect bat passes. It was found that a "1% amplitude level" on

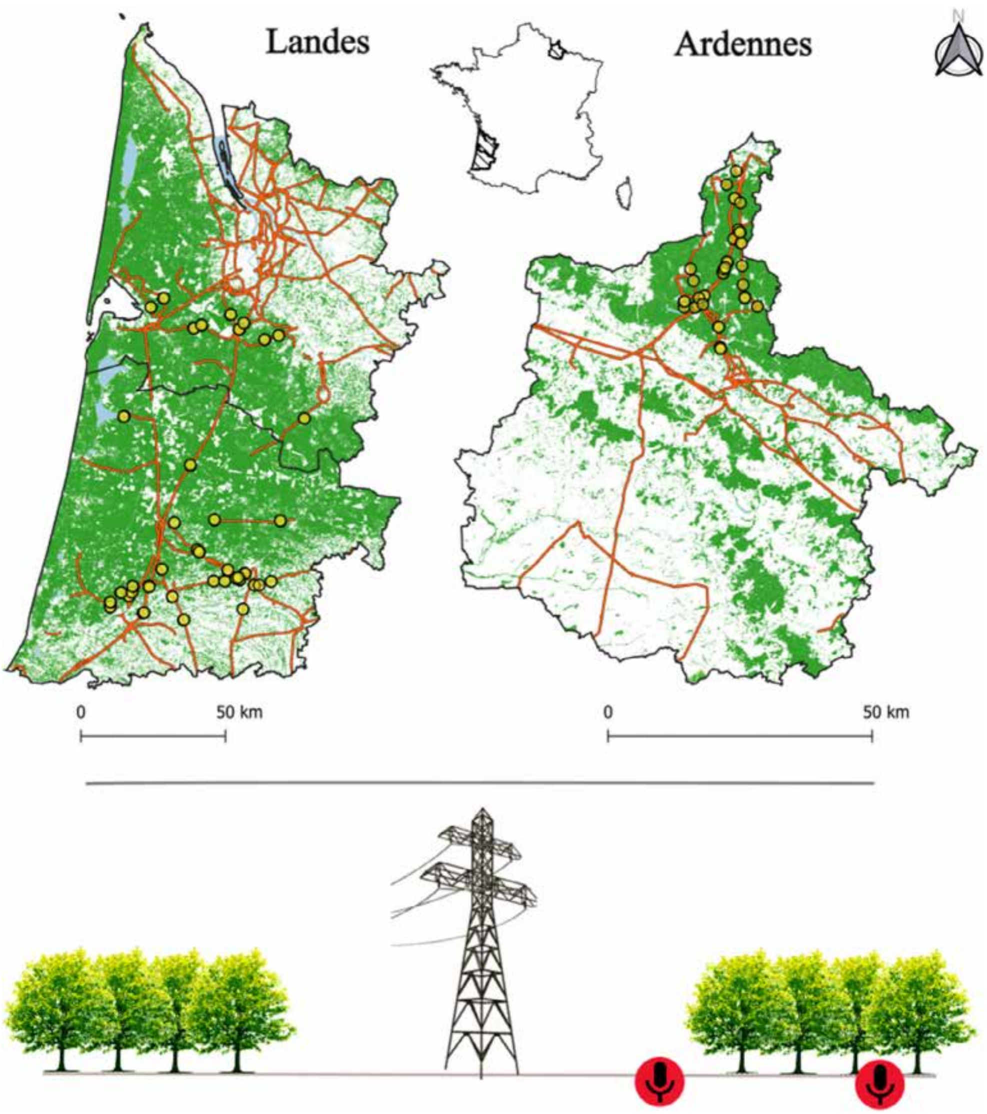

FIGURE 1 Map of the two study areas and all sampling locations. Orange lines represent powerlines, green areas represent the forest areas, and yellow dots are the sampling locations. The bottom part of the figure represents the paired study design in a typical powerline clearing.

Audiomoth triggered, on average, the same bat call in a bat pass as 6 db "Trigger sensitivity" for SM2BAT+. It was also found that bat pass duration after the trigger event was similar between the two recorders, implying that microphone sensitivity was comparable. A total of 69 recording nights were collected within clearings and 38 in adjacent forests. Recordings were collected simultaneously in clearings and forests at 35 sites.

2.2 | Species identification

We defined an acoustic count of bats or bush cricket as one or more echolocation call or stridulation calls within a 5-s interval, which is a commonly accepted standard for bats in Europe (Millon et al., 2015; Stahlschmidt & Brühl, 2012). At the scale of this 5-s acoustic event, acoustic signals were identified at the species level using the Tadarida software (https://github. com/YvesBas/Tadarida-C/; Bas et al., 2017). This software classifies acoustic events into reference classes and provides a confidence estimate for each classification. Classifications of acoustic events are made at two confidence thresholds of 50% and 90% (identification confidence levels [ICLs]). On the one hand, the 50% ICL retains infrequent taxa within large datasets but with average confidence. On the other hand, the 90% ICL only retains identifications associated with high confidence, which obviously restricts the number of taxa considered as well as the size of the dataset used for further analyses. Yet, in order to compare community metrics derived from acoustic monitoring, one would want to keep both a high taxonomic resolution and high confidence. Barré et al. (2019) proposed that testing ecological hypotheses at the two confidence thresholds ensures result robustness against automated identification errors. Here, we present results obtained with the 50% ICL dataset and provide those obtained with the 90% ICL as Supporting Information S1.

Only the results that came out consistently at the two thresholds were considered trustworthy and are comprehensively discussed.

2.3 | Biodiversity metrics

To explore how powerline clearings impact on bush-cricket and bat communities, we inferred four metrics from the acoustic data: the species richness, the total activity, the community specialization, and the community specialization to forests. The species richness, a measure of taxonomic diversity, was assessed as the total number of identified taxa during a recording night. The activity, an acoustic proxy of abundance, was calculated at the species resolution as the sum of acoustic events recorded per night. It was then summed for bat and bush-cricket species, respectively, to provide a total per recording night. Community specialization indices (CSIs) were derived from "Species habitat specialization index" (SSI) over all occurrences available in the French citizen science program "Vigie Chiro" (http://vigienature.mnhn.fr/page/participer-vigie-chiro). They were calculated as the coefficient of variation of a species' relative abundance across 11 habitat classes extracted from Sentinel-2 remote sensing data (Inglada et al., 2019). The latter is considered a proxy of habitat specialization (Julliard et al., 2006). The mean CSI in our dataset was 0.84 ± 0.22 for bats and 0.74 ± 0.23 for bush crickets. Community forest specialization index (CFSI) was derived from the species forest specialization index (SFSI), that is, the frequency of acoustic signals detected in forests, as the arithmetic means of the SFSI weighted by species abundances following (Regnery et al., 2013). The homogeneity of community pairs between clearings and adjacent forests was assessed using Bray–Curtis dissimilarity indices calculated from abundance matrices (Oksanen et al., 2022). This index was chosen because it shows a linear response to the transfer of species abundance from plots to plots (Ricotta & Podani, 2017).

2.4 | Classification of management practices and community metrics

The present study aims to assess how powerline clearings and their management impact bush-cricket and bat communities in forested areas. In France, powerlines cover 100,000 km (https://analysesetdonnees.rte-france.com/reseaux/evolution-reseau). Around 20% are in forests and are thus submitted to close control with vegetation for public security. Recordings were held in forest clearings with two vegetation management regimes. The first category, hereafter labeled "clear-cuts," consists of powerline clearings with repeated resetting of early successional vegetation stages by clear-cutting (Figure S1). The second category, hereafter labeled "IVM," consists of powerline clearings where IVM is promoted.

2.5 | Analyses

We tested the effect of (i) forest edges created by powerline clearings and (ii) the management of vegetation underneath powerlines, by computing two separated datasets. To test for the edge effect on community metrics as well as the management effect on clearing/forest compositional dissimilarity, we focused on acoustic records collected in clearing/forest pairs. Paired records were available at 35 sites for bats and 12 for bush crickets. To evaluate the effect of management practices on community metrics, we focused on acoustic records sampled within clearings only. Corresponding datasets included up to 56 and 31 samples for bats and bush crickets, respectively.

From these, we performed generalized linear mixed modeling using the "glmmTMB" package (Brooks et al., 2017) under the R software v. 4.2.0 (R Core Team, 2022). Separated models ($N = 32$) were built for (i) the two ICLs, (ii) the two taxa groups, (iii) the four community metrics (species richness, activity, CSI, and CFSI), and (iv) the two data subsets focused on forest/clearing pairs or clearing records only. With the aim to test the compositional Bray–Curtis dissimilarity between forest and powerlines clearings, we built four additional models (two ICLs, two taxa, forest/clearing pairs only). All models included a random *station* factor, and bat models included the *region* as an interactive fixed factor to account for potential differences between the two study regions. As very few bush crickets were detected in the "Ardennes," models of bush crickets' diversity focused on the "Landes" only. Pairwise compositional dissimilarity was calculated with "vegan" (Oksanen et al., 2022). Pairwise post hoc tests were produced for all models with Tukey *p* values corrections with the "emmeans" package (Lenth et al., 2023). Hereafter, we present the results obtained with the 50% ICL dataset; the results with the 90% ICL dataset are included in Table S1. Pairwise comparisons are provided in the text only for effects found significant at the two ICLs.

3 | RESULTS

3.1 | Species detected

Overall, the estimated species richness was 5.8 ± 3.4 on average for bats and 2 ± 1.2 for bush crickets. We identified up to 13 bats and three bush-cricket species in clearings of the "Ardennes" region against four and one species of the two taxa, respectively, in adjacent forests (Table 1). In this region, *Pipistrellus pipistrellus* was the most common bat species, recorded in 70% of forests and 97% of clearings. *Platycleis albopunctata* was the most common bush cricket in clearings (21%), whereas *Tessellana tessellata* was the only bush cricket recorded in "Ardennes" forests. In the "Landes" region, up to 16 bat species and 7 bush crickets were identified in clearings versus 15 and 5, respectively, in adjacent forests. Three bat species were recorded in more than 90% of clearings: *Eptesicus serotinus* (100%), *Pipistrellus pipistrellus* (98%), and *Nyctalus leisleri* (93%), where two of them (*E. serotinus* and *P. pipistrellus*) also account for the most frequent identifications (89%) in adjacent forests. In the "Landes," *Tettigonia viridissima* showed up as the most frequent species in both clearings (43%) and forests (75%).

3.2 | Difference between powerline clearings and adjacent forests

Recorded acoustic activity averaged to 746 ± 1066 contacts for bats and 3424 ± 4739 for bush crickets over the entire dataset. We found a significant edge effect on bats species richness at the 50% ICL only (+2.35, $p < 0.001$;

TABLE 1 Activity, mean ± S.D. (n), of bat and bush-cricket species identified within the two study areas at the 50% ICL.

Taxon	Name	Ardennes Forest ($N = 10$)	Ardennes Clearings ($N = 29$)	Landes Forest ($N = 28$)	Landes Clearings ($N = 40$)	SSI	FSI
Bats	*Barbastella barbastellus*		3.8 ± 1.3 (4)	7.4 ± 8.3 (14)	61.9 ± 89.0 (35)	1.96	0.24
	Eptesicus serotinus		3.2 ± 1.7 (6)	18.0 ± 17.4 (25)	470.0 ± 736.0 (40)	0.71	0.1
	Myotis alcathoe		4.0 (1)	12.7 ± 12.2 (3)	17.0 ± 15.1 (4)	1.62	0.45
	Myotis cf. *myotis*	1.5 ± 0.7 (2)	2.6 ± 1.8 (5)	1.0 ± 0.0 (2)	2.5 ± 1.0 (4)		
	Myotis daubentonii	4.0 (1)	108.0 ± 122.0 (7)	6.6 ± 5.8 (5)	13.5 ± 10.2 (20)	2.3	0.06
	Myotis emarginatus			9.7 ± 15.0 (3)	9.8 ± 12.1 (5)	0.94	0.08
	Myotis mystacinus		1006.0 ± 276.0 (3)	4.1 ± 3.8 (9)	19.6 ± 41.6 (9)	0.78	0.25
	Myotis nattereri	27.8 ± 14.6 (6)	97.5 ± 138.0 (19)	4.0 ± 5.9 (9)	11.5 ± 14.2 (26)	1.13	0.07
	Nyctalus leisleri		4.0 (1)	8.0 ± 7.0 (19)	39.9 ± 44.9 (37)	0.6	0.07
	Nyctalus noctula		1.0 (1)	4.0 ± 3.3 (7)	21.9 ± 31.9 (22)	2.31	0.03
	Pipistrellus kuhlii		18.8 ± 7.6 (4)	35.6 ± 72.4 (20)	467.0 ± 788.0 (35)	0.87	0.07
	Pipistrellus nathusii			6.5 ± 0.7 (2)	27.0 ± 23.1 (25)	2.05	0.04
	Pipistrellus pipistrellus	168.0 ± 167.0 (7)	390.0 ± 383.0 (28)	163.0 ± 467.0 (25)	297.0 ± 520.0 (39)	0.68	0.13
	Plecotus auritus		5.0 ± 7.0 (8)		9.0 ± 8.46 (14)	0.98	0.11
	Plecotus austriacus			9.7 ± 15.4 (16)	95.6 ± 251.0 (31)	0.5	0.11
	Rhinolophus ferrumequinum		3.8 ± 1.3 (2)	1.0 ± 0.0 (2)	2.6 ± 1.65 (10)	1.22	0.04
Bush crickets	*Leptophyes punctatissima*		1840.0 ± 357.0 (2)	3179 ± 1755 (5)	4456 ± 3549 (16)	0.77	0.19
	Phaneroptera falcata		12.0 (1)			1.97	0.04
	Pholidoptera griseoaptera		1556.0 ± 1286.0 (5)	599 ± 713 (3)	3624 ± 1688 (4)	0.74	0.2
	Platycleis albopunctata		278.0 ± 266.0 (6)	31 (1)	498 ± 844 (14)	1.08	0.03
	Roeseliana roeselii				93 ± 114 (5)	0.88	0.03
	Ruspolia nitidula			4 (1)	16 (1)	2.01	0.02
	Tessellana tessellata	142.0 (1)			468 ± 264 (2)	1.23	0.01
	Tettigonia viridissima		2334.0 ± 1922.0 (4)	87 ± 122 (12)	1986 ± 1789 (30)	0.6	0.09

Note: Species specific overall habitat specialization (SSI) and forest specialization index (FSI) are also provided.

Tables 2, S1, and S2). The total vocal activity of the bat community was significantly greater in clearings compared with adjacent forests when using both the 50% (×2.66, $p < 0.001$) and 90% (×2.56, $p < 0.001$) ICLs (Figure 2a). None of the bat community specialization metrics varied significantly between clearing edges and adjacent forests. Regarding the fixed effect of the confounded region/season fixed effect, more bat species were recorded in the "Landes" in summer at greater activity levels. The mean CSI in our dataset was 0.84 ± 0.22 for bats and 0.74 ± 0.23 for bush crickets, whereas the mean CFSI was 0.11 ± 0.03 for bats and 0.12 ± 0.05 for bush crickets at 50% ICL.

We detected no effect of powerline clearings in the species richness of bush crickets as compared to adjacent forests. However, the acoustic activity of the bush-cricket community was higher along powerline clearing edges (Figure 2b). Interestingly, while we found no effect on the global specialization of bush crickets to habitats, our results suggest a lower specialization to forest for species recorded along powerline clearing edges compared with adjacent forests (Figure 1c).

3.3 | Clearings management practices

None of the biodiversity metrics describing the bat communities seemed affected by the management regime of powerline clearings. The only predictor that had an influence on the recorded richness and the total activity of bats was the sampling region, with lower scores recorded in the "Ardennes" than in the "Landes."

We found an increase in both species richness and total activity of the bush-cricket community within powerline clearings managed with an "IVM" compared with a "clear-cut" regime, but these effects turned out statistically significant at the 50% ICL only (Table S2). Compositional dissimilarity was significantly higher in IVM compared with "clear-cuts" for both ICLs (Figure 2d).

4 | DISCUSSION

The recorded acoustic activity of bats and bush-cricket communities was higher under powerline clearings compared with adjacent forests. In these powerline clearings, IVM had a contrasted effect on community indicators depending on the considered taxa. Increases in bush crickets' activity and richness were detected at the 50% IC level. Maintenance of secondary vegetation stages in powerline clearings likely reinforced the edge effect induced by the linear clearings on bush crickets, as shown by both the lowering of the forest specialization in

TABLE 2 Detailed summary statistics derived from the determination of acoustic records at a 50% ICL.

			Bats					Bush crickets				
Areas	Position	Practice	Sites	Activity	Richness	CSI	CFSI	Sites	Total activity	Richness	CSI	CFSI
Landes	Forest		28	209 ± 493	5.8 ± 2.6	0.92 ± 0.22	0.12 ± 0.03	14	1341 ± 2055	1.6 ± 0.9	0.75 ± 0.37	0.11 ± 0.04
	Edge	Clear-Cuts	22	1033 ± 1350	8.2 ± 2.3	1.11 ± 0.16	0.11 ± 0.02	16	3689 ± 5925	1.6 ± 0.9	0.71 ± 0.16	0.10 ± 0.04
		IVM	8	1930 ± 1601	10 ± 1.4	1.23 ± 0.10	0.10 ± 0.02	9	9129 ± 5557	3.8 ± 1.3	0.86 ± 0.11	0.10 ± 0.02
Ardennes	Forest		10	135 ± 151	1.6 ± 0.8	0.93 ± 0.25	0.10 ± 0.03	1	142	1	1.23	0.01
	Edge	Clear-Cuts	15	623 ± 432	3.2 ± 1.1	1.03 ± 0.23	0.11 ± 0.02	4	1697 ± 1183	1.2 ± 0.5	0.84 ± 0.20	0.11 ± 0.07
		IVM	14	552 ± 566	2.9 ± 1.3	1.09 ± 0.42	0.12 ± 0.04	5	3138 ± 3101	2.6 ± 0.6	0.94 ± 0.33	0.11 ± 0.06

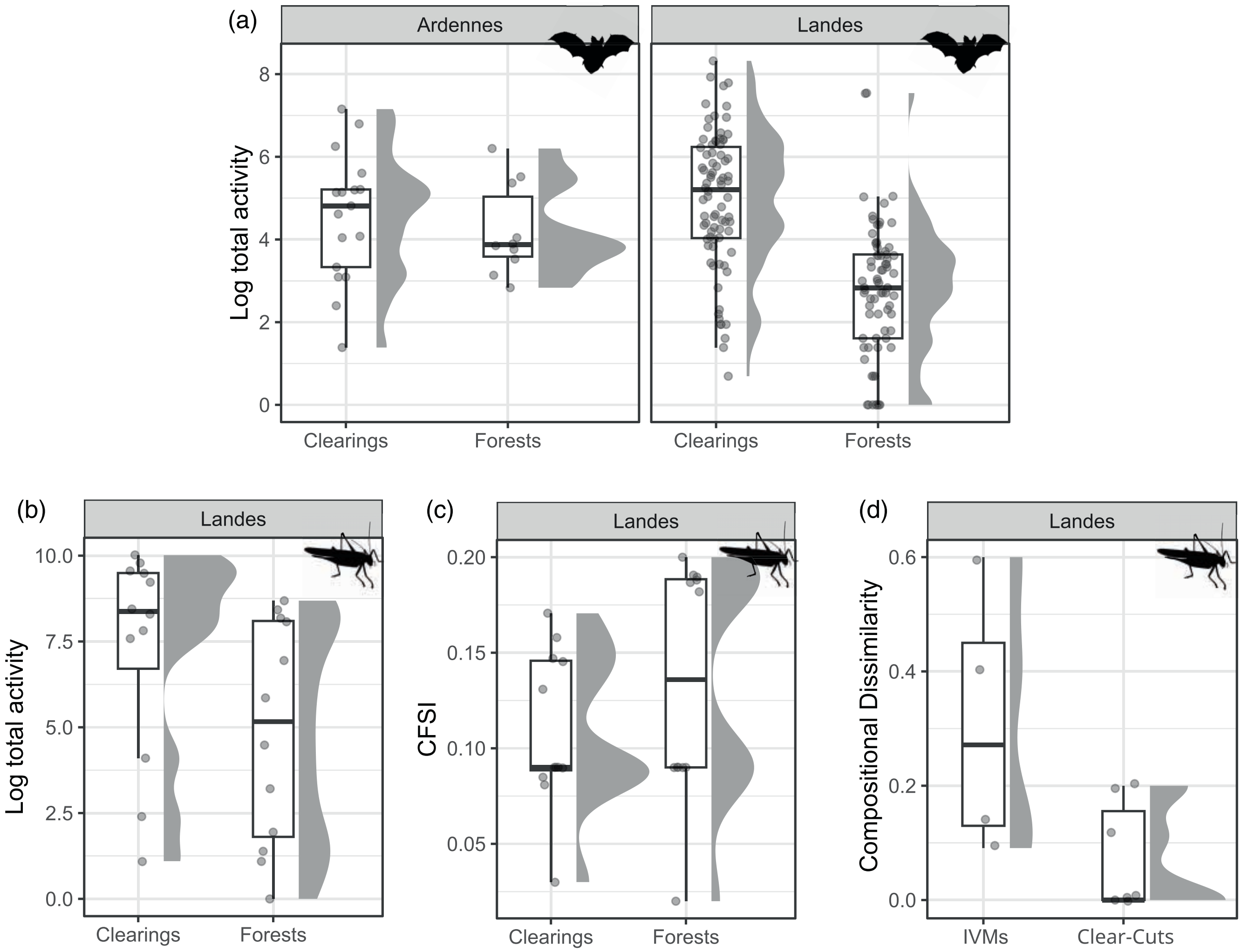

FIGURE 2 Significant differences observed between clearings and adjacent forests: (a) on the total activity of bat communities in the two study regions; (b) on the total activity (log-transformed for better visualization) of the bush-cricket community in the "Landes"; and (c) on the CFSI of bush-crickets community in the "Landes." (d) Increase in the pairwise community dissimilarity for bush crickets recorded in IVM of powerline clearings in the "Landes" region.

clearing communities and the increased compositional dissimilarity of IVM regimes.

4.1 | Edge effect

Our results add new evidence for the edge effect: biodiversity metrics for acoustically active vertebrates were higher at forest edges induced by clearings, even in proximity to high-voltage powerlines. Previous studies have also shown no negative effects of powerline clearings on birds (Evans & Gates, 1997; Tryjanowski et al., 2014) and small mammals (Clarke et al., 2006).

In our study on bats, acoustic activity was significantly higher along forest edges than within the forests themselves. That is consistent with previous observations along the North Carolina (USA) pine forest edges (Morris et al., 2010). In those forests, edges presented a higher total activity of seven bat species. Another study recorded bat movements in forest edges (Kalcounis-Rueppell et al., 2013). The main result was that bats' movements were mainly parallel to edges. Kalcounis-Rueppell et al. (2013) proposed that bat species mostly use continuous forest edges, such as the powerline clearings studied here, as movement corridors. The positive influence of forest edges on bat species richness only stood out from the 50% I.C. dataset and is, therefore, to be read with caution. Further, in the context of habitat modification, a local increase in species richness itself is not sufficient to conclude a positive conservation output (Kerbiriou et al., 2009). Within our studied sites, bat communities are dominated by edge species such as *Pipistrellus pipistrellus* (Frey-Ehrenbold et al., 2013; Lacoeuilhe et al., 2016; Verboom & Huitema, 1997), which contribute to this positive effect. Yet, it is worth mentioning the increased activity of all Myotis species in clearings compared to adjacent forests in the two study regions. Forest clearings and generation stands, particularly when patches cut are small, are indeed known to provide suitable foraging habitats for these forest species (Divoll et al., 2022).

No negative effect of powerline clearings on insects was found in the literature review provided by Villemey et al. (2018), mostly referring to works on hymenopterous pollinators. This extends to bush crickets, according to our results, which is unsurprising because they are mostly bioindicators of open habitats and grasslands in particular (Gerlach et al., 2013). We observed an increased acoustic activity of the bush-cricket community within clearings of the "Landes" compared with adjacent forests. Consistently, trapping in a similar forest/edge-paired setting reported higher species richness along the edges of a planted forest in South Africa (Pryke & Samways, 2012). The same team also demonstrated that the total acoustic activity of bush crickets was significantly higher at forest/grassland interfaces compared with four forest and two grassland states (van der Mescht et al., 2021). Lacoeuilhe et al. (2016) highlighted that the density of wooded edges increased the total activity of mobile bush-cricket species, but this was not true for sedentary species. Within our studied sites, we found a similar result since communities were dominated by mobile bush-cricket species (such as *T. viridissima*).

Only five species of bush crickets were recorded in the northern region of "Ardennes," so the region was not included in our analyses. The few calls that were recorded were located within powerline clearings. The dominant species was *Platycleis albopunctata*, a thermophilic species that is likely shifting its range northward as a result of global warming (Griebeler & Gottschalk, 2010; Poniatowski et al., 2020). Powerline clearings may thus provide dispersal corridors to xeric and thermophilic species, such as *P. albopunctata*, which may affect community compositions in the longer term. This is what we expected and tends to be confirmed by the decrease in bush-cricket community specialization to forest we found in powerline clearings of the "Landes."

Increased activity combined with similar community richness and specialization suggests that powerline clearings are mostly porous to bat and bush-cricket communities and that they do not represent a sharp ecological barrier, which has already been shown for understory vegetation (Hamberg et al., 2009). Further, the absence of edge effect on the general specialization of species to habitats may also reflect the fact that most French forests—as it is the case throughout Europe—are highly managed and thereby made of secondary, regenerating forest stands displaying low complexity and biodiversity (Bengtsson et al., 2000). Obviously, these observations do not rule out the possibility of fragmentation occurring at a landscape scale. One could, for example, expect that the density of powerline clearings in a landscape would affect the fitness or behavior of forest specialist species (Basille et al., 2013), but this is out of the scope of the present study.

4.2 | Management

In this context, the way in which vegetation is managed could be determinant in shaping powerline clearing effects on forest biodiversity. At our study sites, the bush-cricket community had a different response to IVM regimes, allowing for secondary vegetation successional stages. According to our dissimilarity analysis, IVM favors the establishment of powerline clearings of bush-cricket communities, which are slightly different from those inhabiting the forest they cross. This pairwise difference appeared lower between the forest and powerline clearings where primary vegetation successional stages are frequently reset (between 3 and 12 years). This matcheswith our expectations that the regime of habitat disruption in "clear-cut" management does not allow for the settlement of an independent bush-cricket community and, therefore, mostly relies on immigration from surrounding habitats. Few similar outputs have already been reported following the reduction of either (i) the frequency or (ii) the intensity of vegetation cuts under powerlines. Eldegard et al. (2017) documented a positive correlation between the compositional dissimilarity of communities along the powerline clearing/forest continuum and the age of the powerline clearing. This relation reflects the fact that clear-cuts progressively transform into more suitable habitats over time. Benefits from a lowering of the cutting intensity under powerline have also been reported. As an example, it has been suggested that removing ligneous debris when cutting powerline clearings may favor bee species richness (Steinert et al., 2018).

4.3 | Limits and prospects

The use of acoustic proxies comes with a risk of identification bias favoring the detection of low-frequency and high-intensity calls over high-frequency and low-intensity echolocation pulses, which may bias the detection of some species. Logistical constraints also forced us to deploy different acoustic detectors at two seasons in two regions so that all these effects are confounded in our models. This limitation does not allow us to discuss the community differences between the two regions beyond the knowledge available on species biogeography and forest quality. The timing of the study also constrained the design to synchronic and comparative hypothesis testing. This approach only considers the present and limits our capacity to integrate the historical states of the study forests. Indeed, powerlines may have been installed either by opening linear in mature forests or directly in natural open habitats such as meadows. Therefore, it cannot be ruled out that, in some cases, forest patches surrounding powerlines are the result of 50 years of vegetation succession and that powerline clearings' management maintained open habitats. Studying the effect of powerline clearings through a Before-After-Control-Impact at the time scale of a forest stand would provide more detailed and reliable conclusions on that point. However, such a study would imply a time frame of 50–80 years, which sounds unrealistic.

Considering these limits, further research may explore (i) specific effects of the different IVM, including temporal aspects such as the cutting frequency and the clearing age when relevant (Table S3), (ii) the complexity and age of forest patches in which clearings are located, or (iii) clearings effects at a broader landscape scale. While our results suggest that vegetation management in powerline clearings could impact herbivorous and secondary consumer species like bush crickets more than flying predators like bats, disentangling vegetation and edge effects throughout trophic networks and among functional groups would finally provide useful complementary knowledge from both conservation and management points of view.

Our results suggest that linear edges created in the forest by powerline clearings represent increased movement opportunities for bats and, most particularly, edge-foraging species. European edge-foraging bat species are mainly generalist, so that a lowering of the bat community specialization to habitat was expected in clearings as compared to adjacent forests. Yet the two-specialization metrics we tested here did not show evidence of such a decline at a local scale. For bush-cricket species, powerline clearings provide new suitable habitats, particularly for species requiring thermophilic conditions, which are not threatened neither. Yet, where powerline clearings already exist, IVM is likely to promote the establishment of independent and specialist bush-cricket communities. Overall, our results suggest that the conservation potential of powerline clearings in French forests may principally lies in the novel habitats provided to common bats and bush-cricket species. To get the most of these conservation opportunities (Baker et al., 2019; Gaston & Fuller, 2007) in forest powerline clearings, we call for further joint efforts between the scientific community and environment managers to develop innovative management regimes supported by dedicated biodiversity monitoring.

AUTHOR CONTRIBUTIONS

Lisa K. M. Garnier, Yves Bas, and Christian Kerbiriou designed the study. Cyprian Kauffmann collected the data. Martin Thibault, Yves Bas, and Christian Kerbiriou analyzed the data. Martin Thibault wrote the first draft. All authors contributed to the final version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The salary of Martin Thibault was funded by R.T.E., and Lisa K. M. Garnier is a permanent member of R.T.E. staff.

DATA AVAILABILITY STATEMENT

Summary of the collected data is provided within the manuscript. Full acoustic recordings are publicly available from the portal of the citizen program "Vigie-Chiro" (http://vigienature.mnhn.fr/page/participer-vigie-chiro).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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